TISA Working Group Update

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CERES Science Team Meeting

Virtual Covid-19 Meeting, April 28-30, 2020

OUTLINE

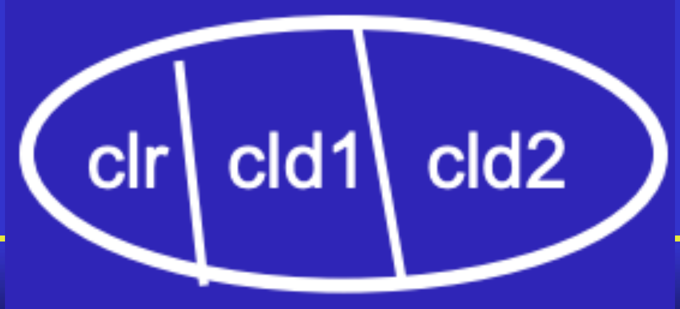
- FluxByCloudType product and public release status
- GEO shortwave narrowband to broadband progress for Edition 5
- TISA Edition 5 coding status
- GEO and imager calibration group collaboration with the Goddard MODIS and VIIRS calibration teams
- GEO daily calibration monitoring improvements

FBCT

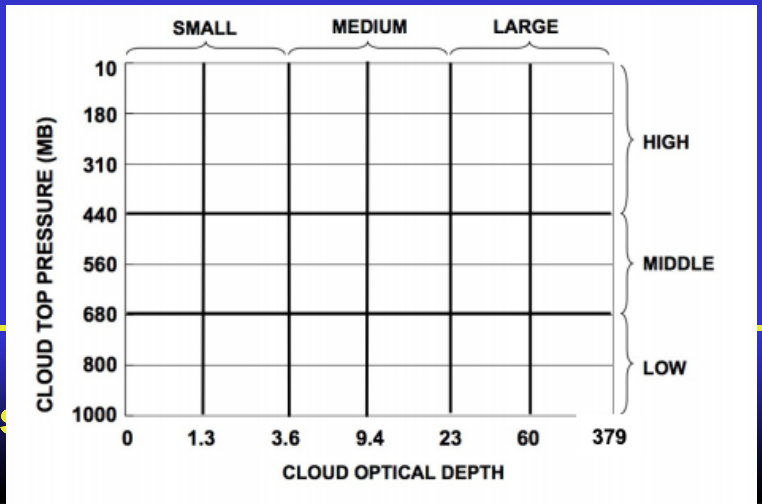
Flux By Cloud Type (FBCT) Product

- Terra+Aqua gridded daily and monthly averaged daytime (SZA<82, no nighttime or twilight) fluxes stratified by cloud top pressure and optical depth
- Compute BB fluxes for each of the 42 Pc-Tau cloud type bins
  - Compute BB fluxes for each sub-footprint area from empirical NB to BB coefficients based on homogeneous CERES footprints
  - Normalize the computed BB flux to the CERES observed flux at the footprint level
  - Validated by comparing the total (42 cloud type average) flux to the SSF1deg-month flux (lite product containing Terra+Aqua)

CERES footprint

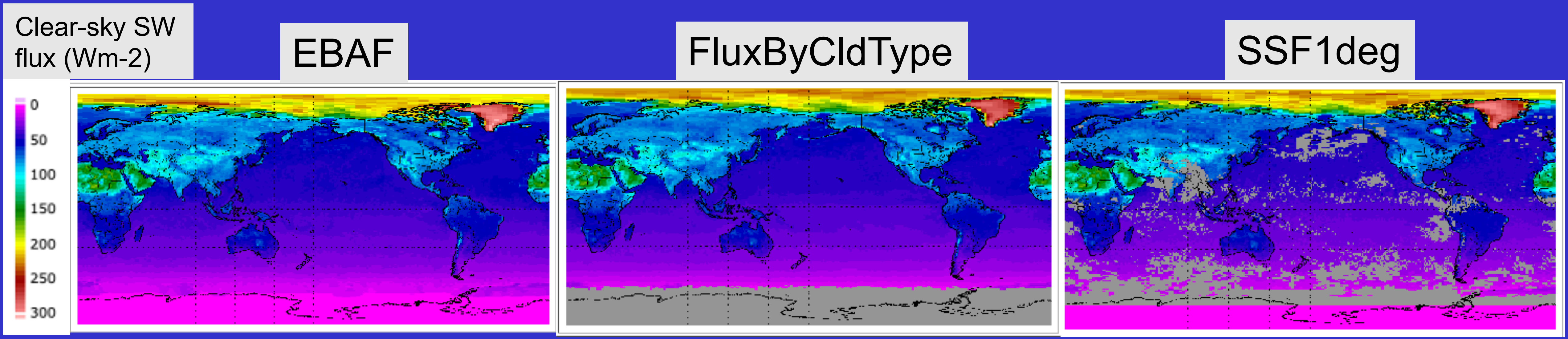


42 Pc-Tau cloud type bins

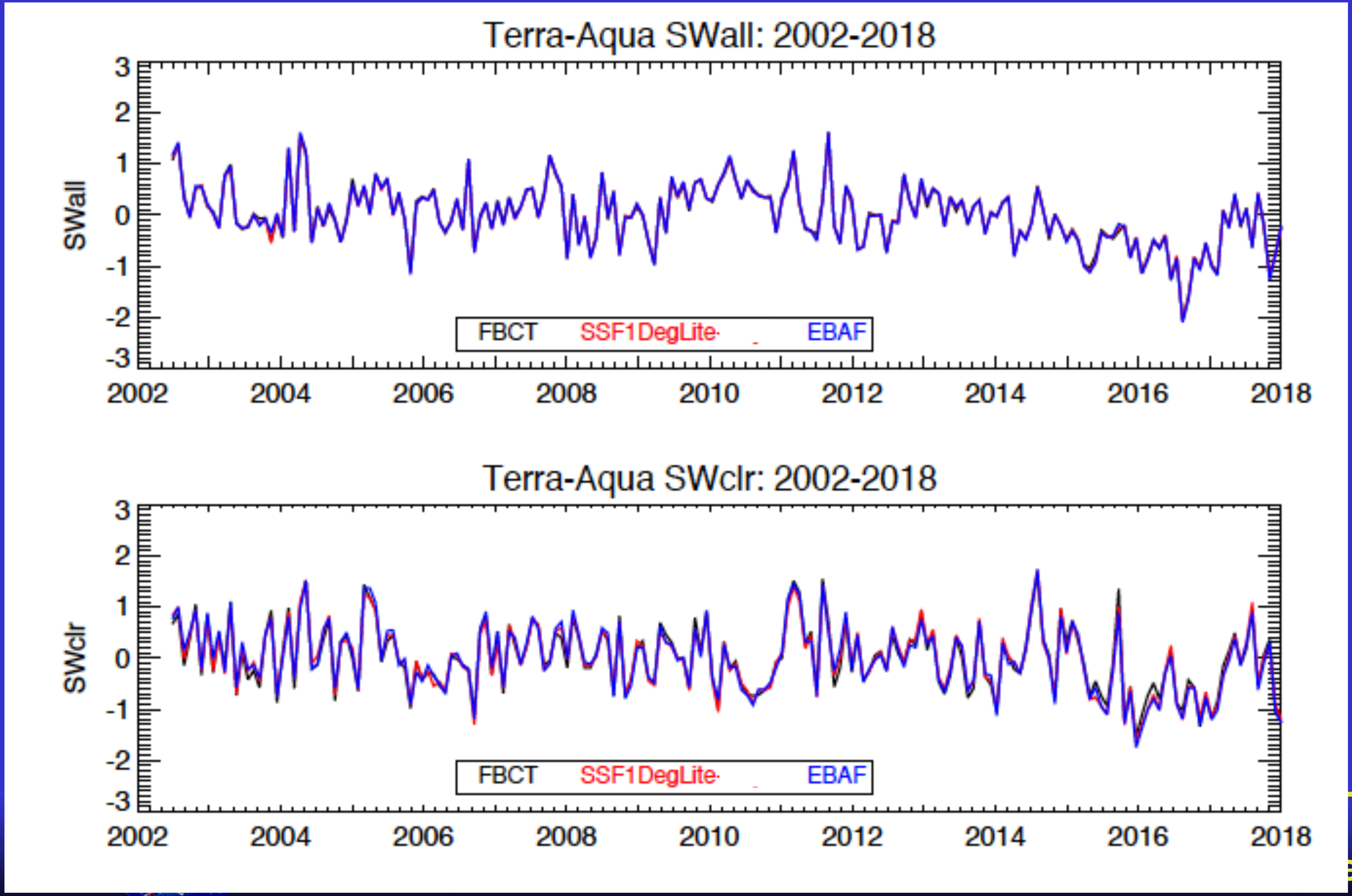


Comparison of FluxByCldType clear-sky SW coverage

- Since the FluxByCldType clear-sky SW flux is based on subfootprint fluxes it will provide complete geographic coverage over the month, similar to the EBAF product
- The SSF1deg product relies on completely clear-sky SSF footprints



Comparison of FBCT, SSF1deg-lite, and EBAF SW flux anomalies



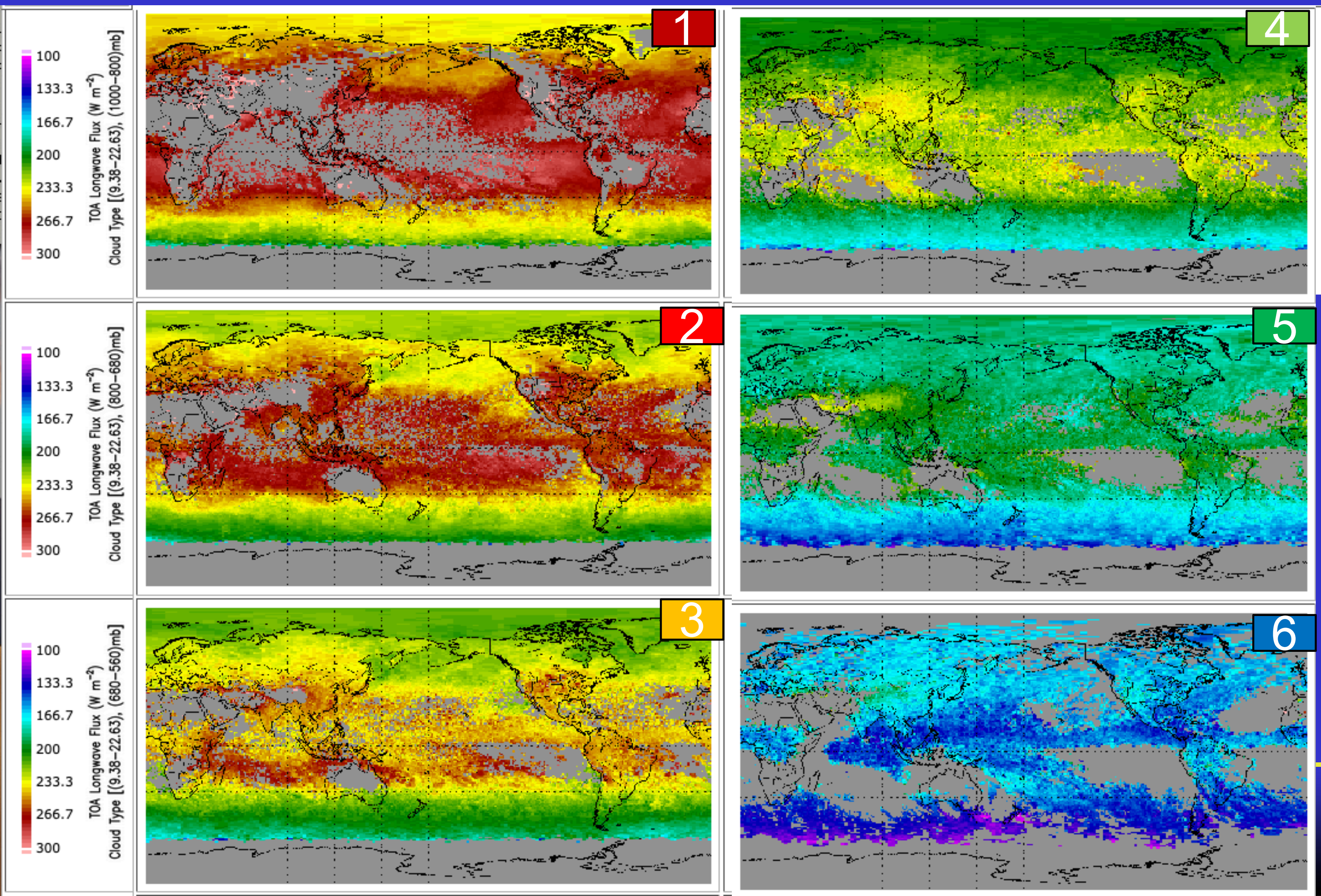
- Only regions with SZA<82° are used for the comparison
- It is not a true global mean

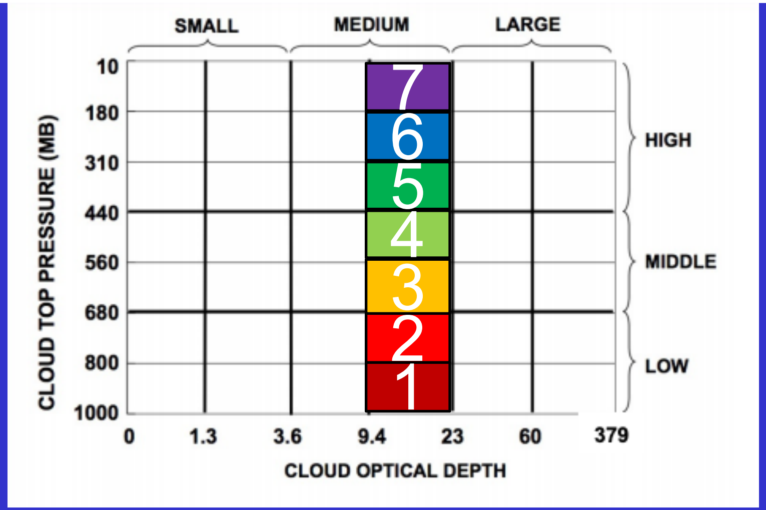
- The FBCT clear-sky SW is based on sub-footprint fluxes similar to EBAF

- The July 2002 to Dec 2017 SW clear-sky flux EBAF mean is 1.02 times the FBCT mean, which is very close to the EBAF SW calibration adjustment to reflect the ocean heat storage term.

58.79 (FBCT)*1.02 = 59.96 (EBAF)

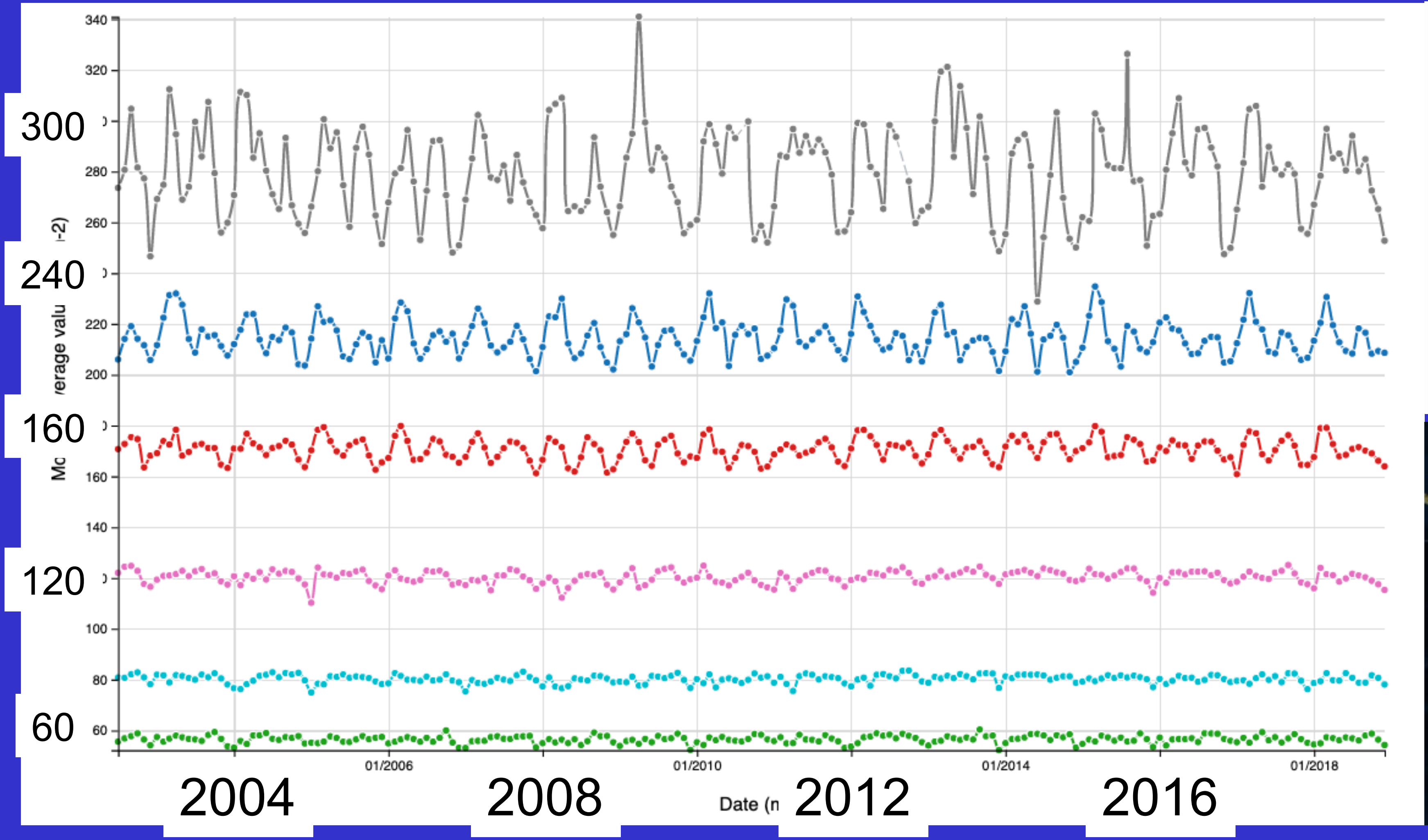
July 2002, Regional FBCT LW flux (Wm-2) by cloud type

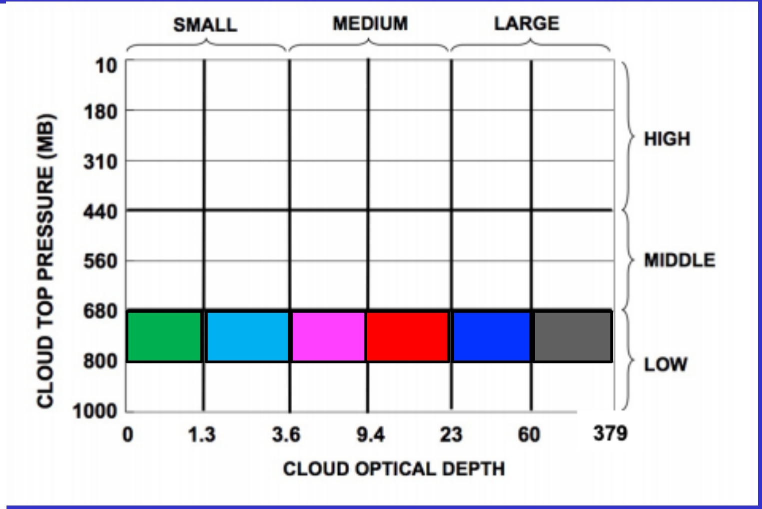




Plotting option available now

SW flux (Wm-2) by cloud type

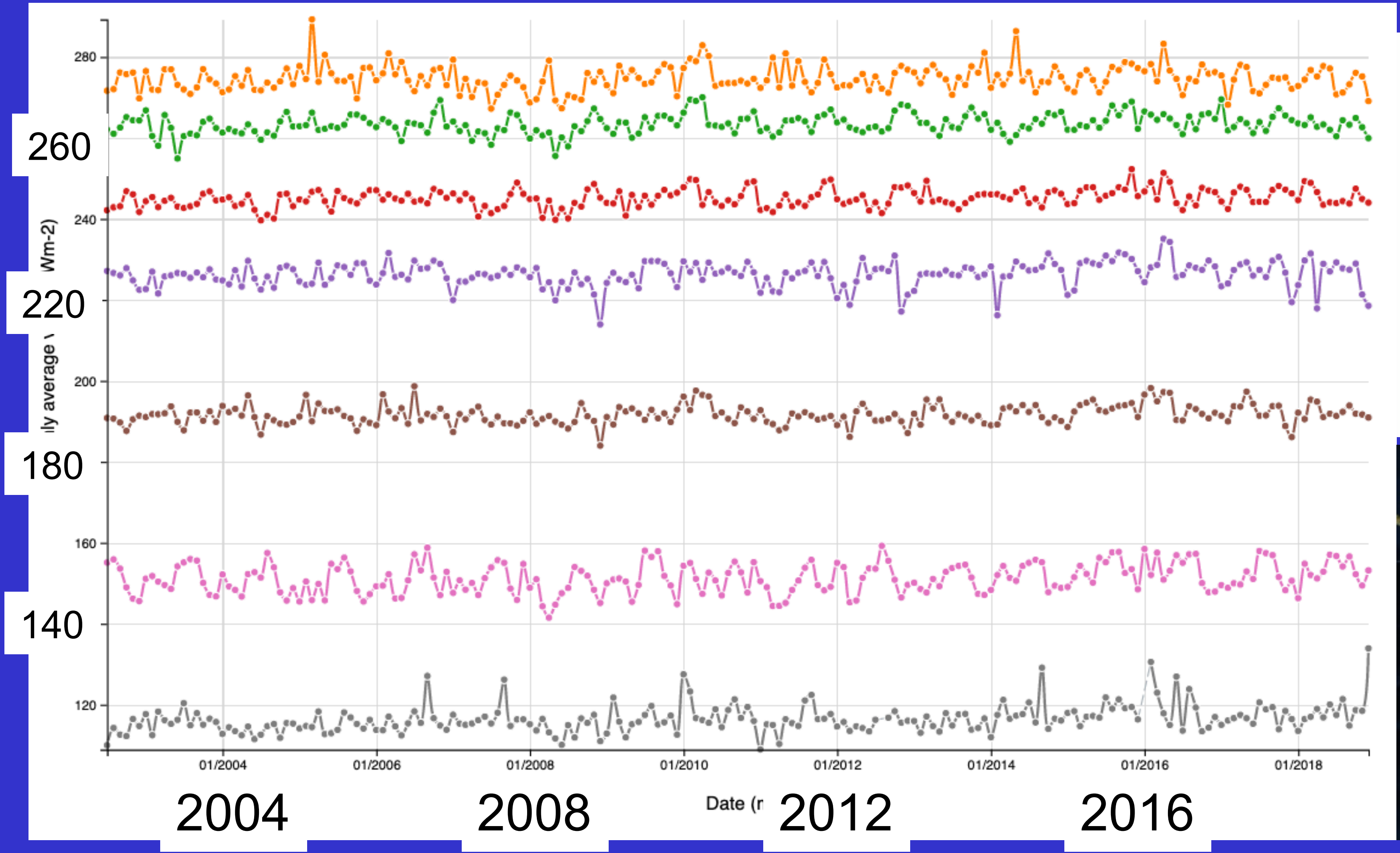


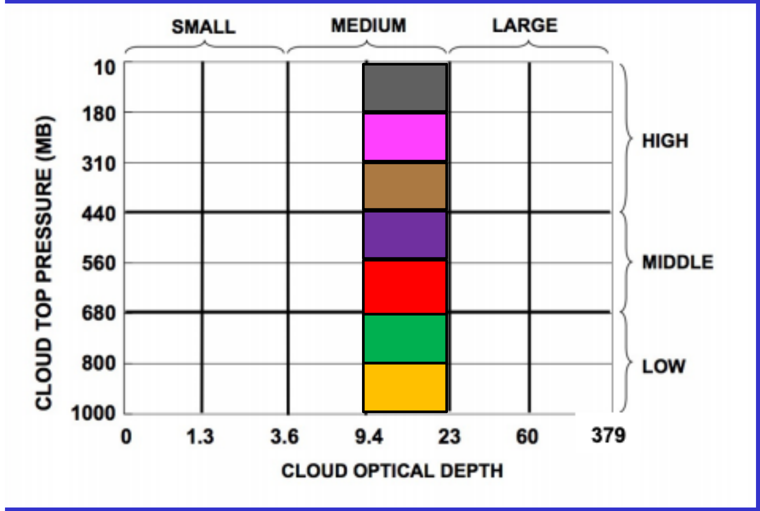


Plotting option being developed

Note the flux stability over the record indicating robust SW NB to BB

FBCT LW flux (Wm-2) by cloud type

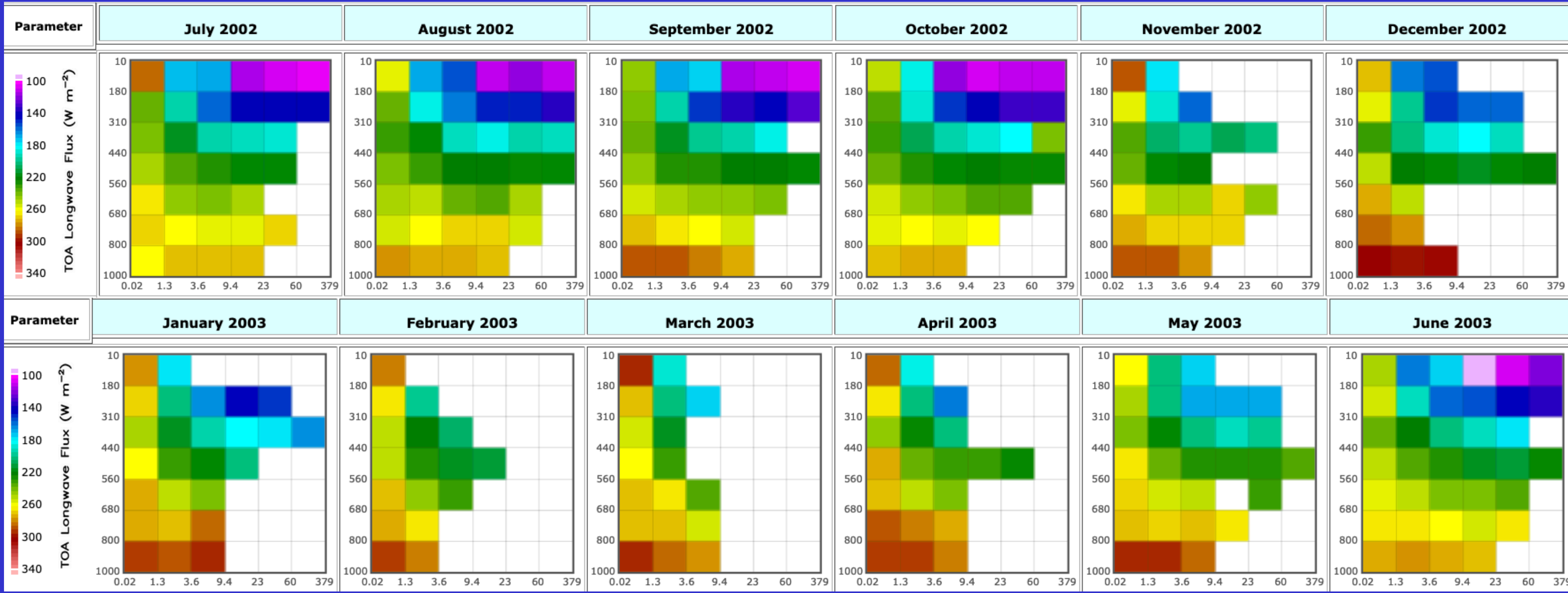




Plotting option being developed

Note the flux stability over the record indicating robust LW NB to BB

FBCT LW flux (Wm-2) by cloud type



Plotting option being developed

FluxByCldTyp public release status

- Delivered the FBCT-day/month code in late February 2020
  - Processed 20 years of data on the science side and production and found 4 months with differences.
  - Found the bug on April 14
  - Reprocessed and should be available next week on the CERES ordering tool on Friday May 8, 2020
- The CERES subsetter is ready for users to order FluxByCldTyp-Month
  - FluxByCldTyp-Day not ready
  - Working on DQS and journal paper
- Preliminary FBCT datasets were provided to beta testers and they provided valuable feedback.
  - Scott et al. 2020, Observed Sensitivity of Low Cloud Radiative Effects to Meteorological Perturbations over the Global Oceans, Journal of Climate publication using the FBCT dataset is in the review process.
  - Lazaros Oreopoulis also examined the FBCT dataset, mentioned that the GSFC MODIS clouds and CERES clouds differed

SW NB to BB

GEO SW NB to BB Ed5

- Convert GEO visible channel directly to broadband radiance using hyper-spectral RTM
  - Eliminate the Ed4 two step process of converting GEO to MODIS-like and then using empirical MODIS-like to BB radiance (Ed4 SW NB to BB codes no longer exist)
  - Each GEO will have its own customized RTM LUT by convolving the RTM hyper-spectral radiances with the GEO spectral response function
- Continue to use the TRMM ADMs to convert BB radiance to flux
  - TRMM orbit precesses and provides complete solar zenith angle sampling
- Continue to inter-calibrate GEOs with Aqua-MODIS to maintain consistent calibration across GEO platforms in both space and time
- If time permits use multiple GEO imager channels to improve GEO SW NB to BB, might be an Ed6 improvement

DIScrete Ordinate Radiative Transfer (DISORT) model

- Same RTM used to un-filter the CERES broadband radiances (Lusheng RTM version)
- ~ 2500 (0.2µm to 5µm) hyper-spectral radiances
- H_2O, O_3, O_2, CH_4, CO_2, CO and NO from the LBLRTM HITRAN 2008 database
- Two habit ice model defined by De and tau
- Cox and Munk clear-sky ocean BRDF model at 8 Maritime aerosol optical depths
- Clear-sky land IGBP surface reflectance BRDF from MODIS MCD43C1 product
- TISA has the code and is able to run the RTM to generate more LUTs if needed

Atmosphere
tropical
Midlatitude summer
Midlatitude winter

Ice cloud De
21.86
46.34
115.32

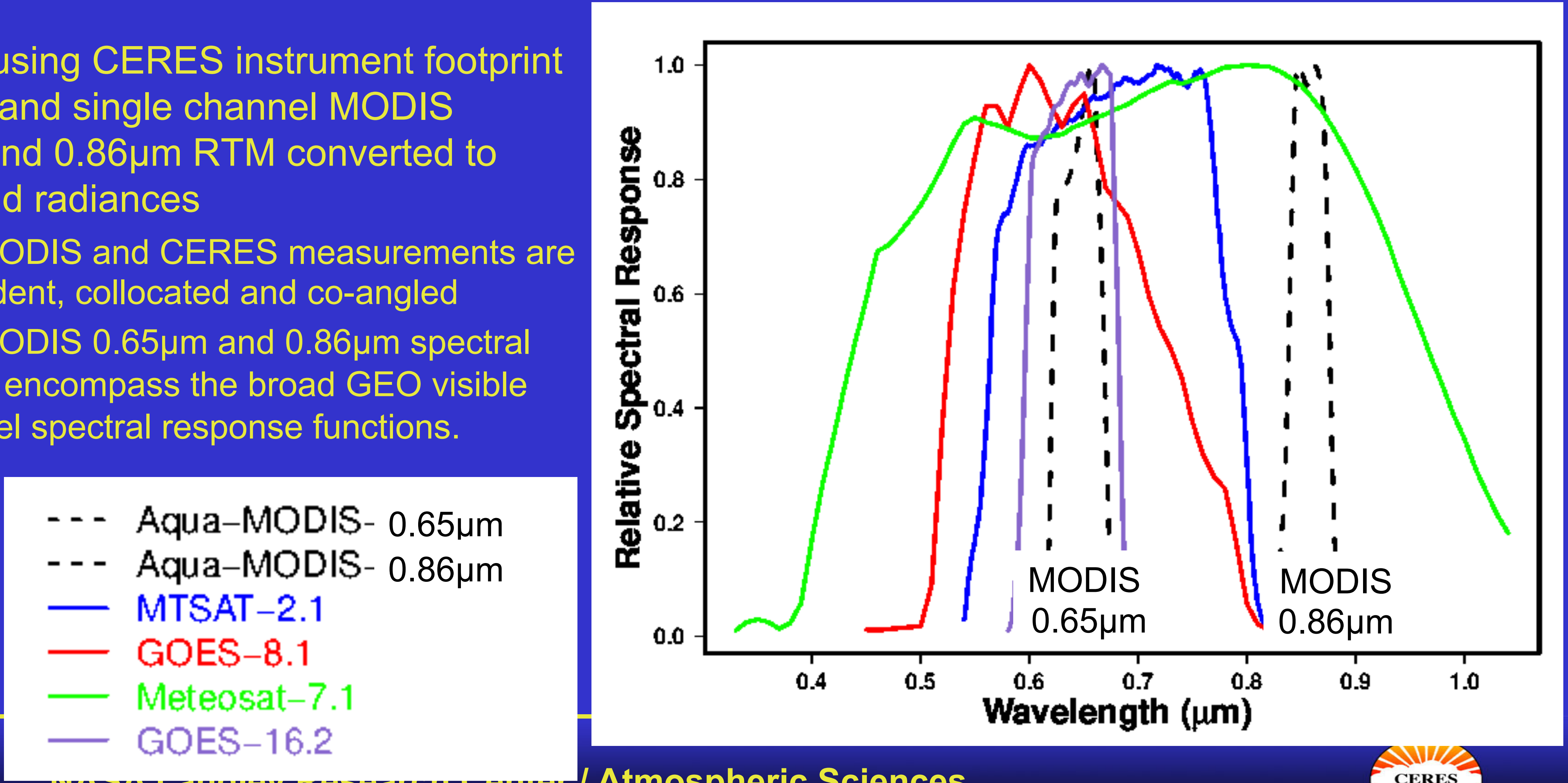
Water cloud De
8.0
20
32
50

Water cloud layer
1-4 km

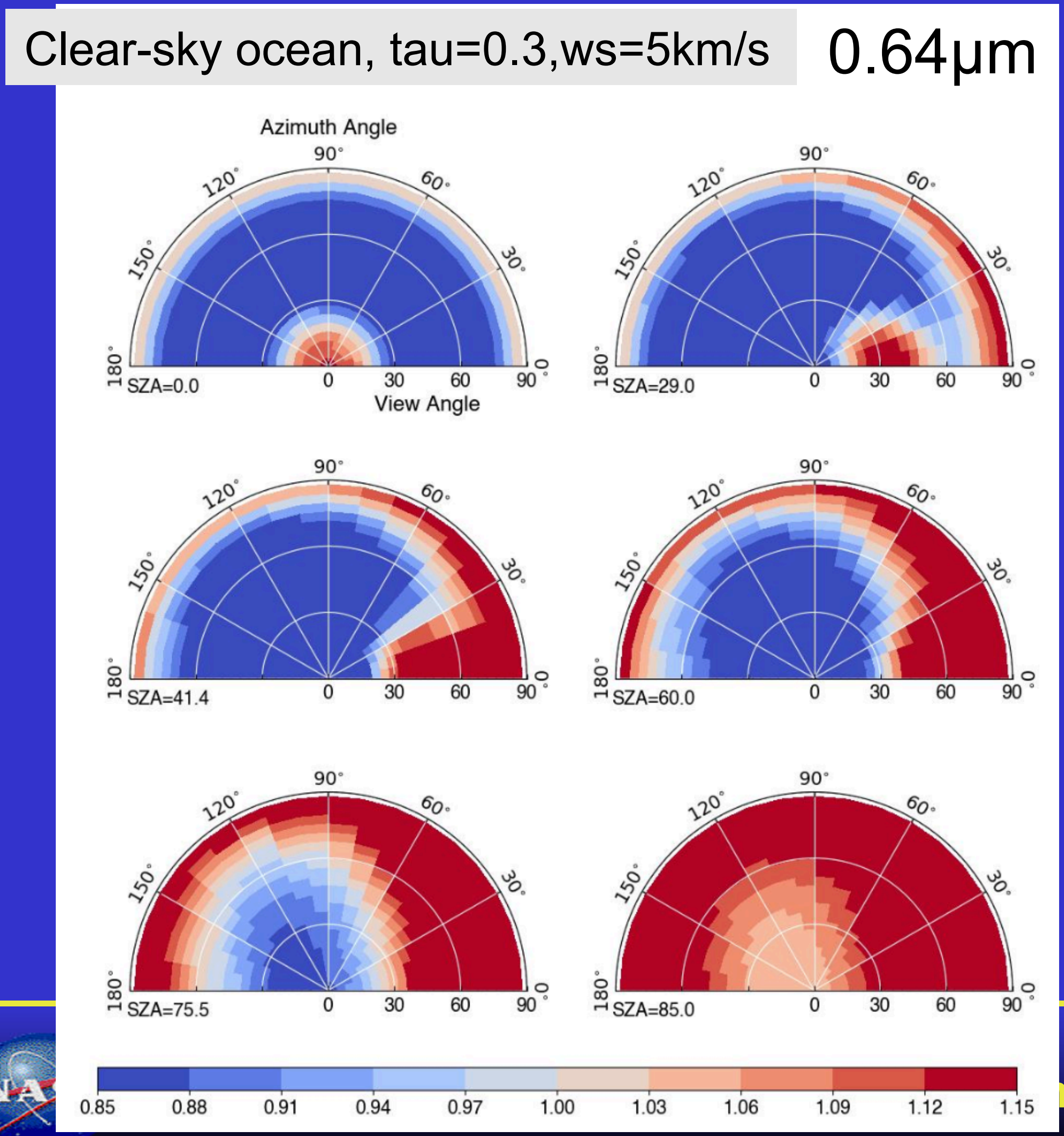
Ice cloud layer
9-11 km
7-17 km

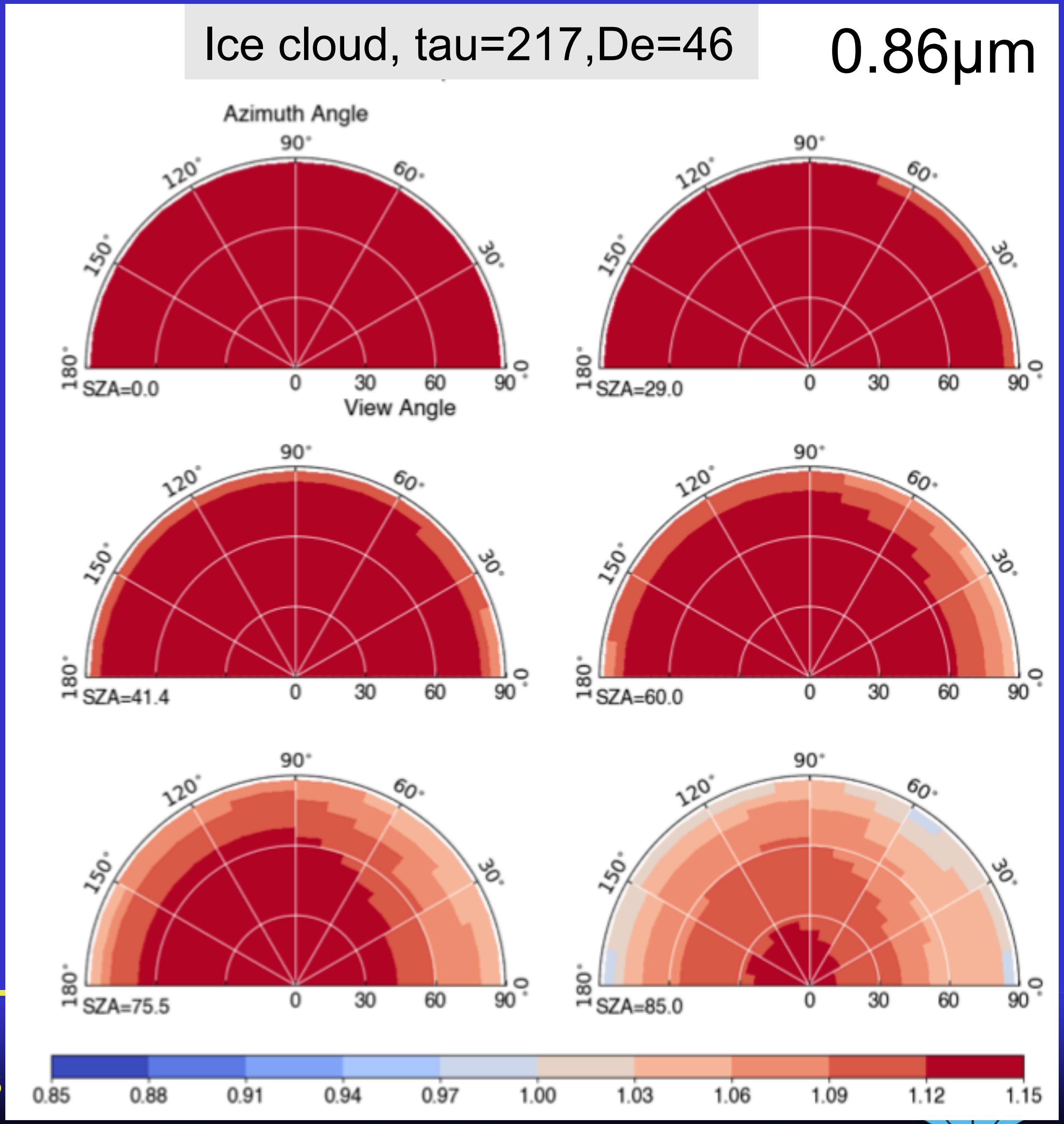
Step 1: Validate the RTM NB to BB LUT using SSF MODIS 0.65µm and 0.86µm and CERES radiances

- Validate using CERES instrument footprint radiance and single channel MODIS 0.65µm and 0.86µm RTM converted to broadband radiances
  - The MODIS and CERES measurements are coincident, collocated and co-angled
  - The MODIS 0.65µm and 0.86µm spectral bands encompass the broad GEO visible channel spectral response functions.

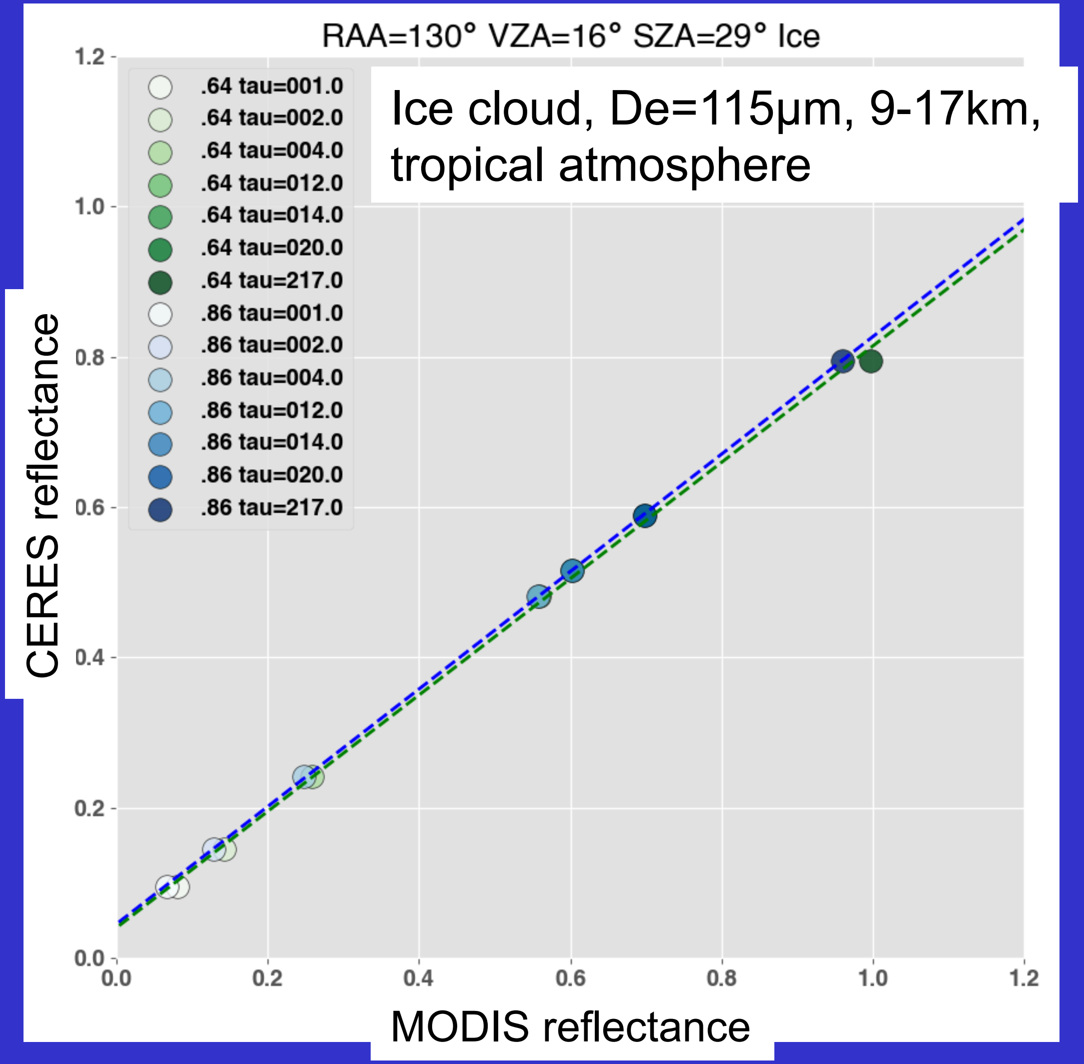


MODIS NB(0.65µm)/BB BRDF ratio LUTs





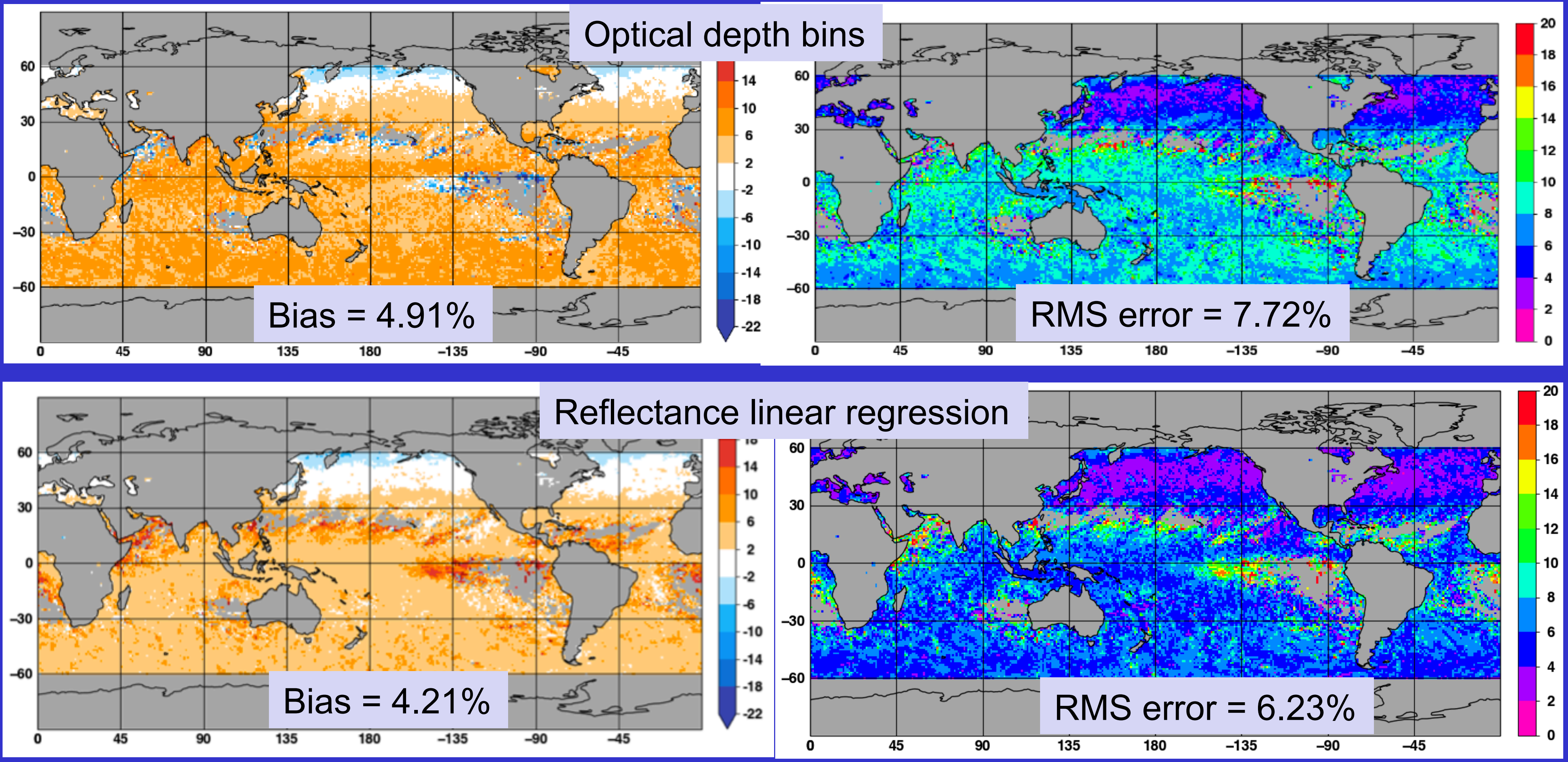
NB to BB conversion strategies



- Use the observed cloud retrieved optical depth bin to to find the NB to BB ratio
- The GEO and MODIS observed optical depths may not be consistent with one another or with the RTM

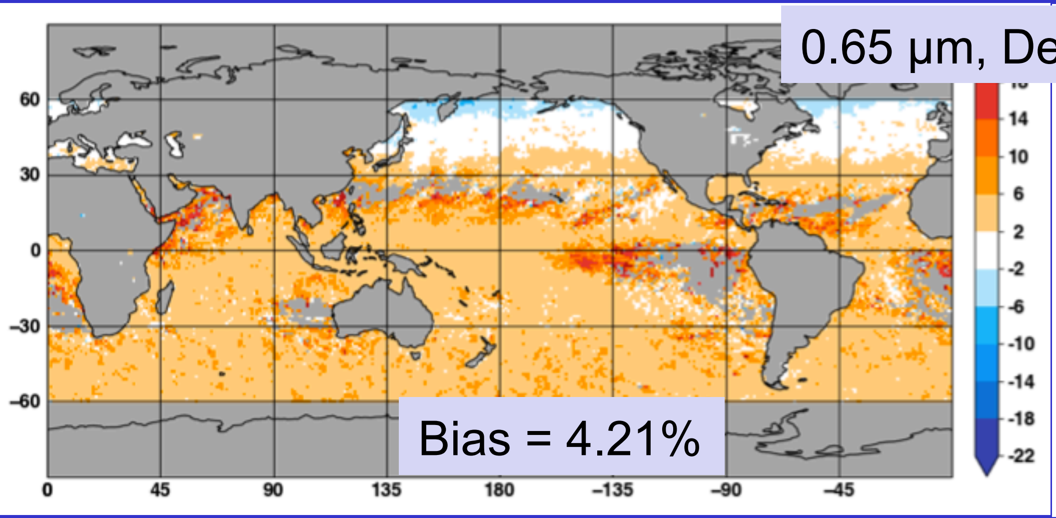
- Rather than use optical depth, base the NB to BB ratio on the NB reflectance.
- Perform a linear regression of the optical depth reflectances to find the NB to BB ratio
- The cloud NB and BB reflectance ratio has a linear dependency for visible wavelengths <1μm for optical depths > 1

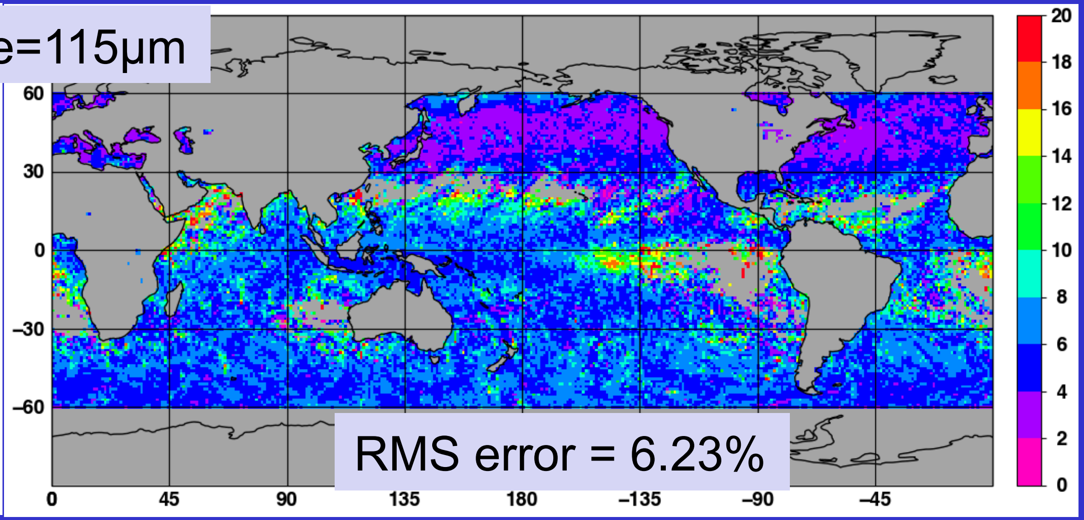
Jan 2010, MODIS 0.65µm RTM BB – CERES radiance, Ice Cloud footprint>90%, De=115µm



- Accessing the LUT by reflectance rather than by optical depth reduces the uncertainty in the NB to BB conversion
- Linear interpolation between NB reflectances should reduce the bias and RMS error for thin ice clouds.

Jan 2010, Ice Cloud SSF footprints > 90%



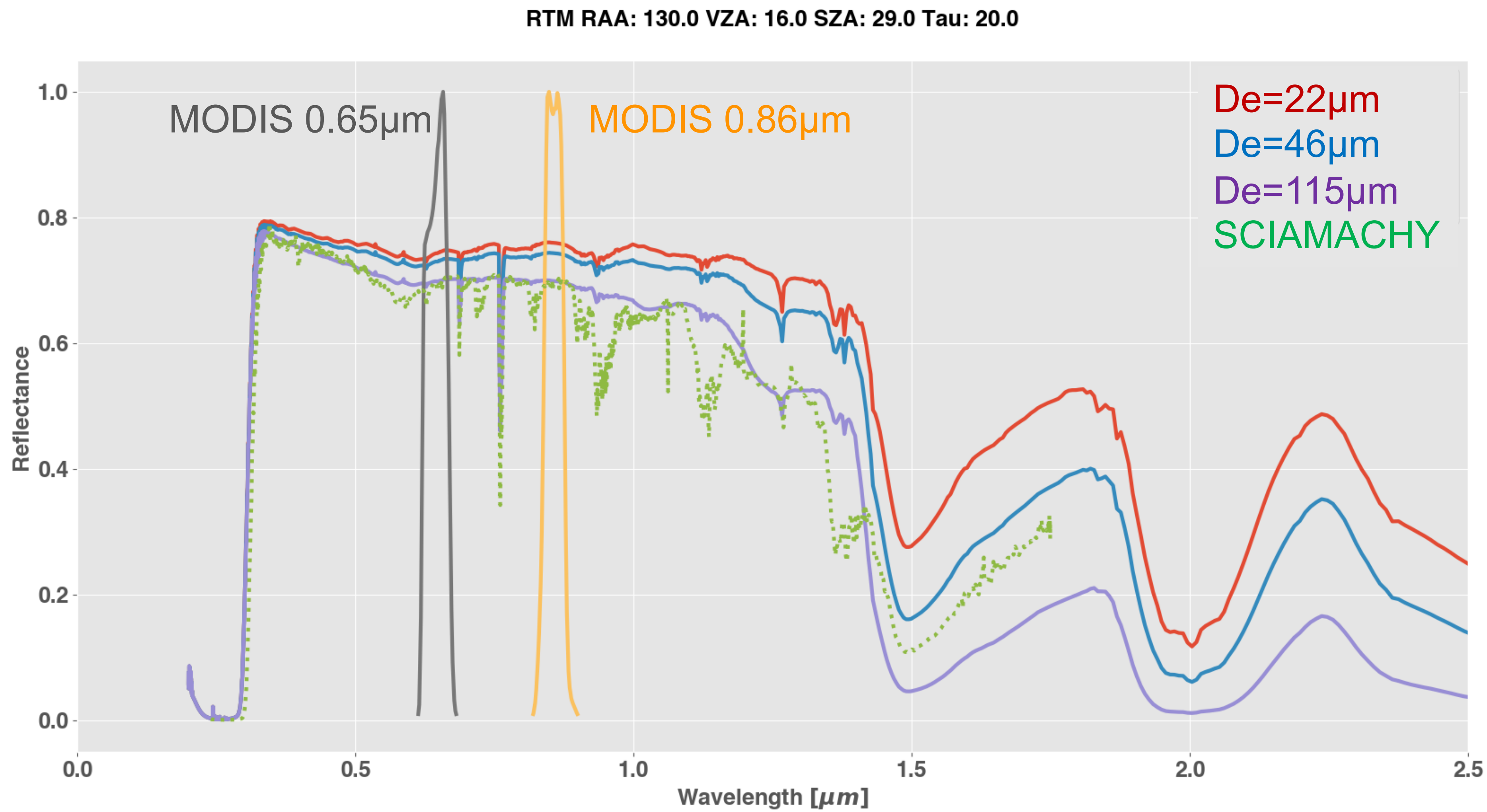


MODIS RTM BB - CERES

De (%)	Bias 0.65µm	RMS 0.65µm	Bias 0.86µm	RMS 0.86µm
21.86 µm	10.1	11.7	9.4	12.9
46.34 µm	8.1	9.6	8.0	11.6
115.32 µm	4.2	6.2	5.9	9.8

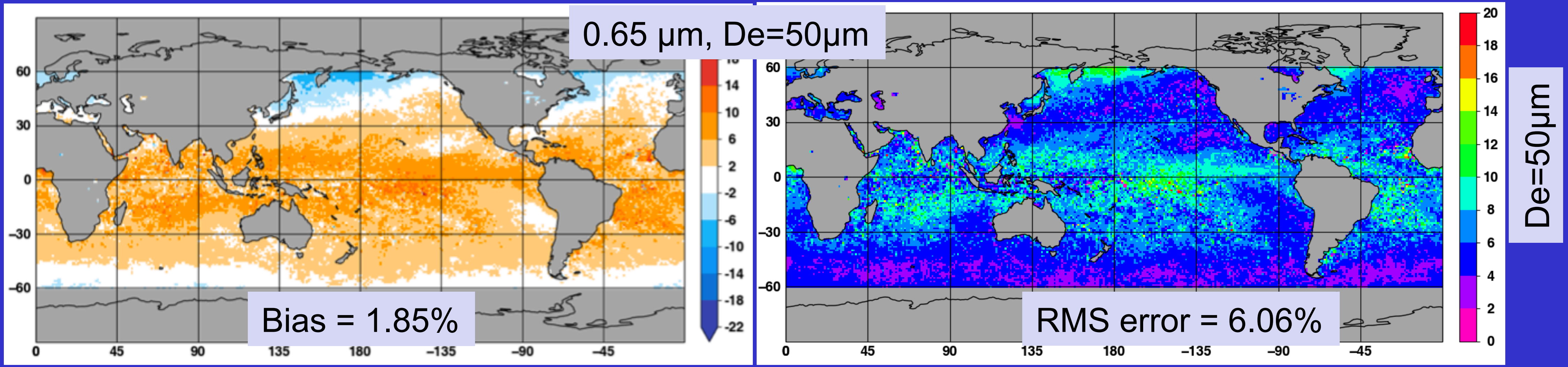
- The largest ice particle size distribution provides the lowest biases and RMS errors

Ice Cloud Particle Size Spectra comparison with SCIAMACHY



SCIAMACHY best fits the RTM De=115μm reflectances for shorter wavelengths

Jan 2010, Water Cloud SSF footprints > 90%

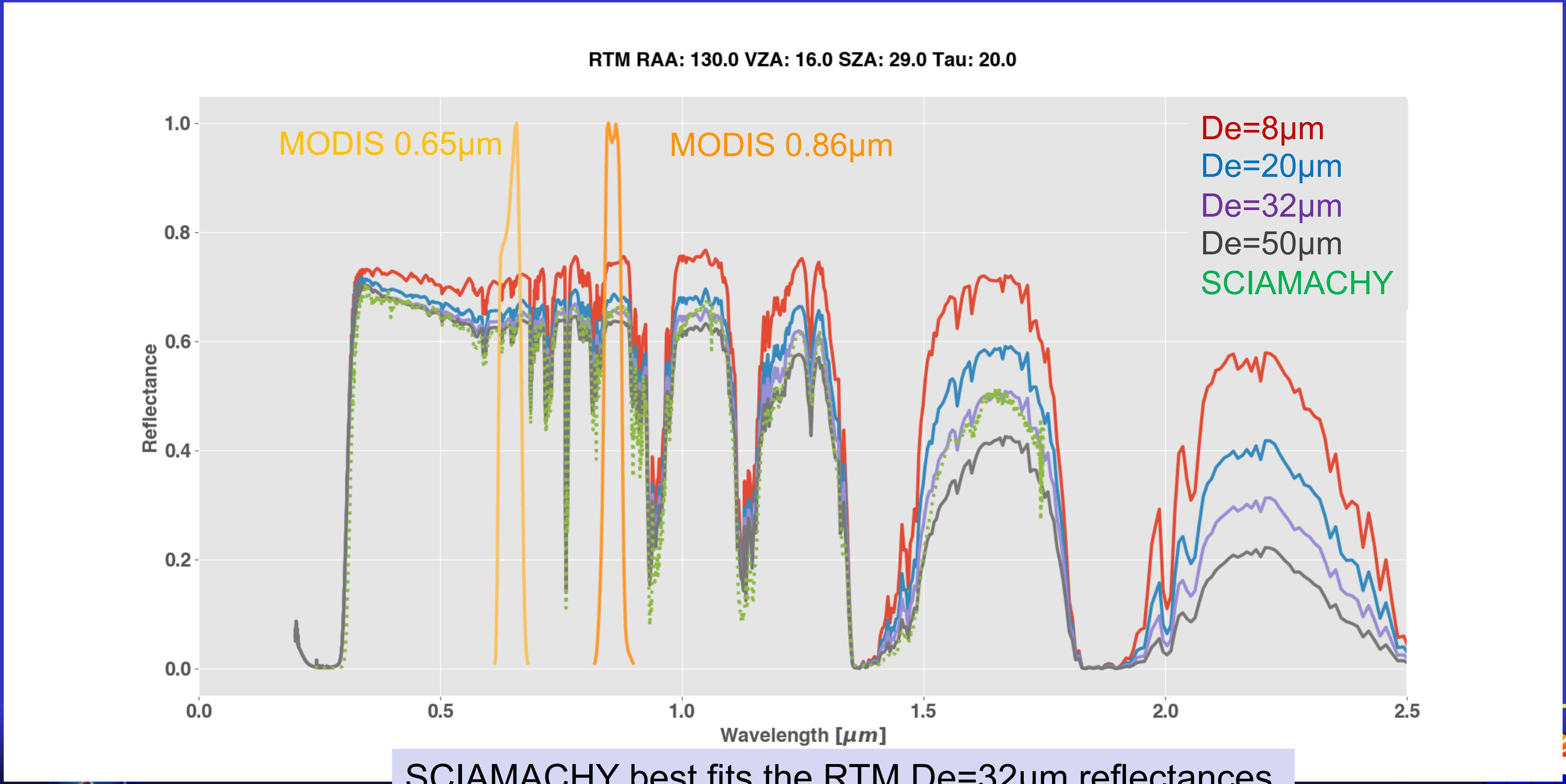


MODIS RTM BB - CERES

De (%)	Bias 0.65µm	RMS 0.65µm	Bias 0.86µm	RMS 0.86µm
8 µm	6.5	8.8	7.4	9.6
20 µm	4.8	7.4	7.2	9.8
32 µm	3.0	6.6	6.5	9.4
50 µm	1.9	6.1	5.8	8.8

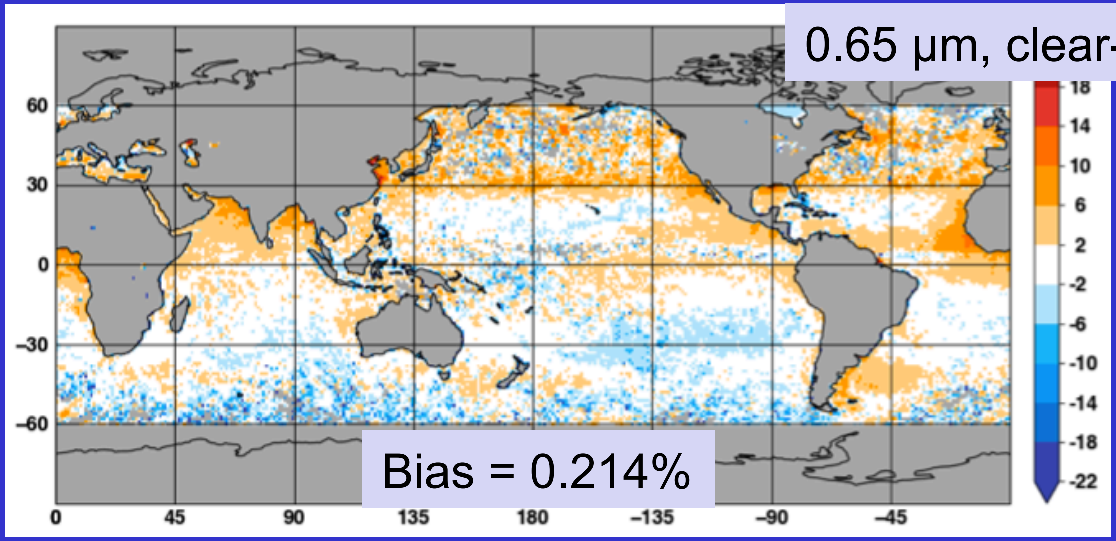
- The largest water particle size distribution provides the lowest biases and RMS errors

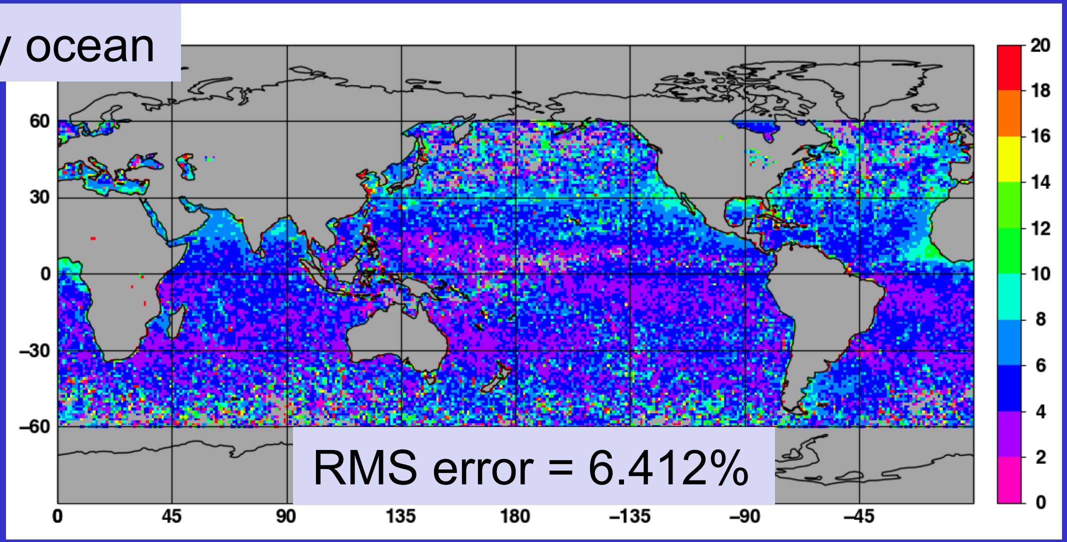
Water Cloud Particle Size Spectra comparison with SCIAMACHY



SCIAMACHY best fits the RTM De=32μm reflectances

Jan 2010, Clear-sky ocean SSF footprints > 90%





MODIS RTM BB - CERES

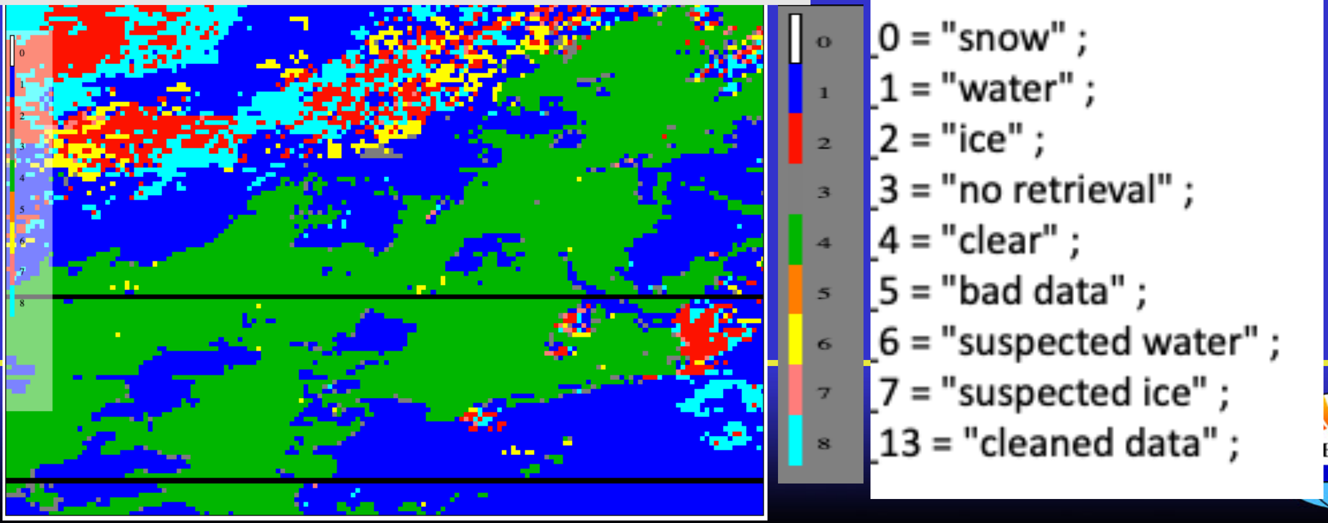
De (%)	Bias 0.65µm	RMS 0.65µm	Bias 0.86µm	RMS 0.86µm
Clear-sky	0.2	6.4	3.2	11.6

Non homogeneous footprints

- Each SSF footprint may have up to 3 sub-footprint imager scene type channel radiances.
  - Each sub-footprint radiance is individually converted to broadband radiance
  - If the sub-footprint is of mixed phase, the dominant phase is used
  - Future analysis, proportionally assign to an ice or water cloud
- Similarly, Each GEO pixel is assigned as clear, ice, water cloud and can be optimally stratified for a given 1° region

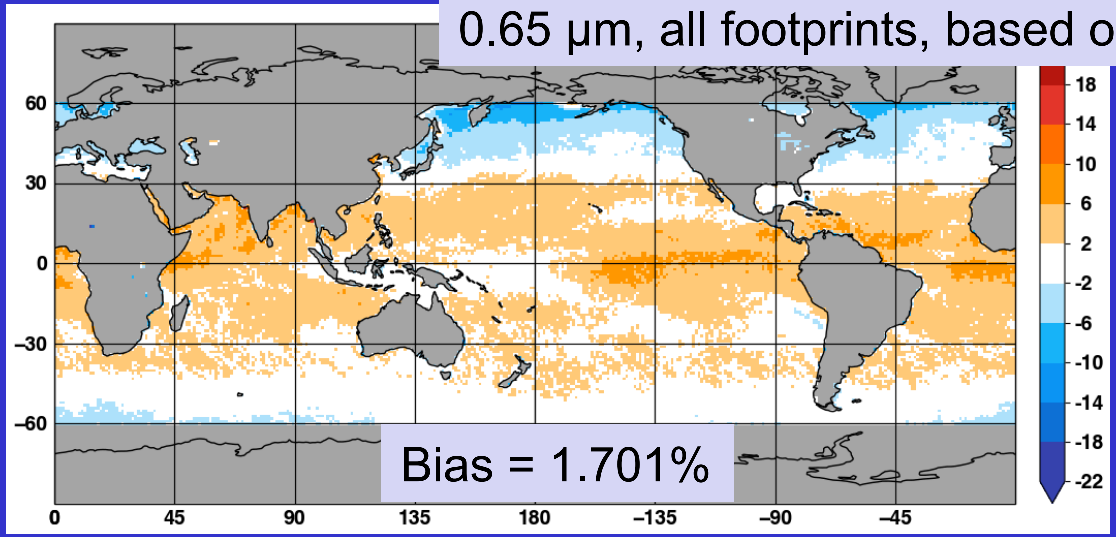
CERES footprint

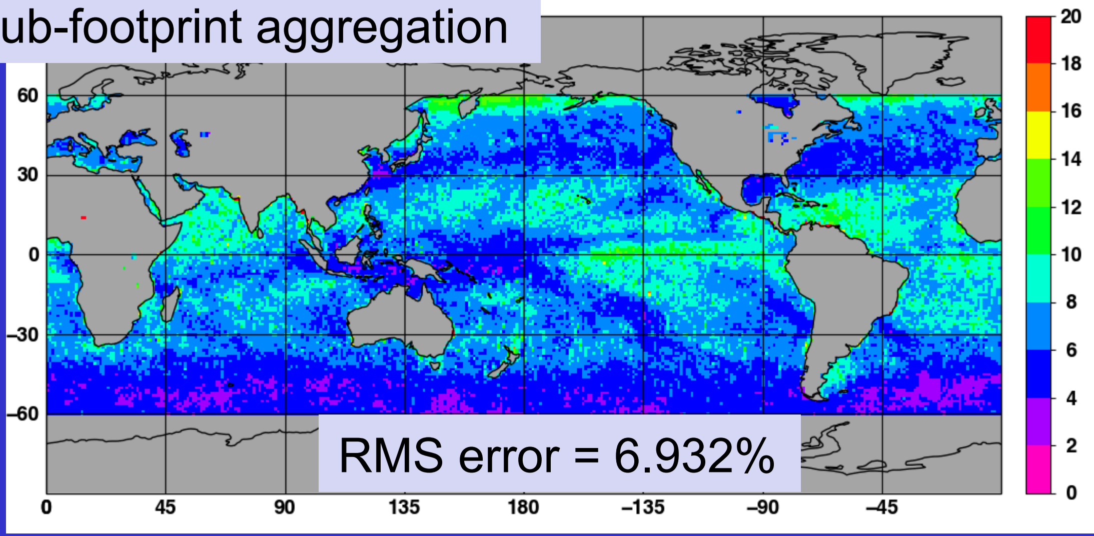
GOES-15 pixel-level identifier May 30,2019, 1 GMT



Jan 2010, All footprints

0.65 µm, all footprints, based on sub-footprint aggregation





MODIS RTM BB - CERES

De (%)	Bias 0.65µm	RMS 0.65µm	Bias 0.86µm	RMS 0.86µm
Clear-sky	1.7	7.0	4.0	9.0

SW NB to BB conclusions

- Finalize the selection of LUTs and bin interpolation
- Test with coincident GEO visible and Terra and Aqua CERES radiances
- Perform SW NB to BB with Terra measurements (including normalization) and compare the GEO BB flux with the Aqua observed
- Test with coincident Meteosat visible and GERB radiances for all hours during the day
- Best implemented when the instantaneous gridded GEO netCDF image files are read in to allow flexibility in cloud property stratification
  - This is part of the TISA Edition 5 improvements
- Multiple visible channel SW NB to BB
  - This is part of the Edition 6 efforts

TISA Edition 5 coding

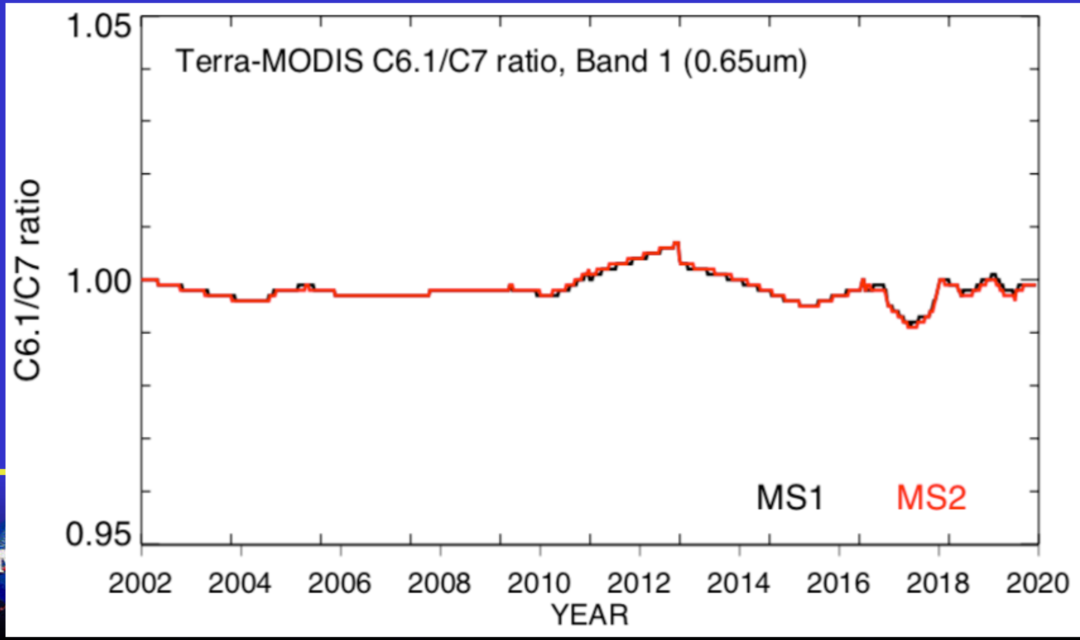
TISA Edition 5 code status

- For Ed4, TISA has delivered FBCT, SSF1deg-N20
  - The SSF1deg-N20 have replaced the CERES WN channel with the LW channel
  - Comparing SSF1deg Aqua and N20 temporally averaged flux differences to tie the records seamlessly
- Plan on internal processing of SYN1deg-N20-only and SYN1deg-Aqua-only Ed4 products
  - The SYN1deg-N20 has replaced the CERES WN channel with the LW channel and provides GEO NB to BB for both
  - Compare the GEO derived clouds, fluxes and surface fluxes between Aqua and N20
- The SW NB to BB algorithm is on track for Ed5 implementation
- The 2-channel cloud code has been converted to pixel-level netCDF output format
- The SYN1deg and SSF1deg and lite product codes are being merged
  - flexible gridding and time box systems are in place
  - Next multi-parameter arrays to facilitate the incorporation of new parameters
  - Next work on SW and LW flux TISA library functions
- EBAF scripting – should be ready by the end of May for the next round of EBAF processing
- Ed5 gridding improvements, where SARB, FlashFlux and TISA SW/LW NB to BB routines will be implemented at the GEO pixel level before gridding.

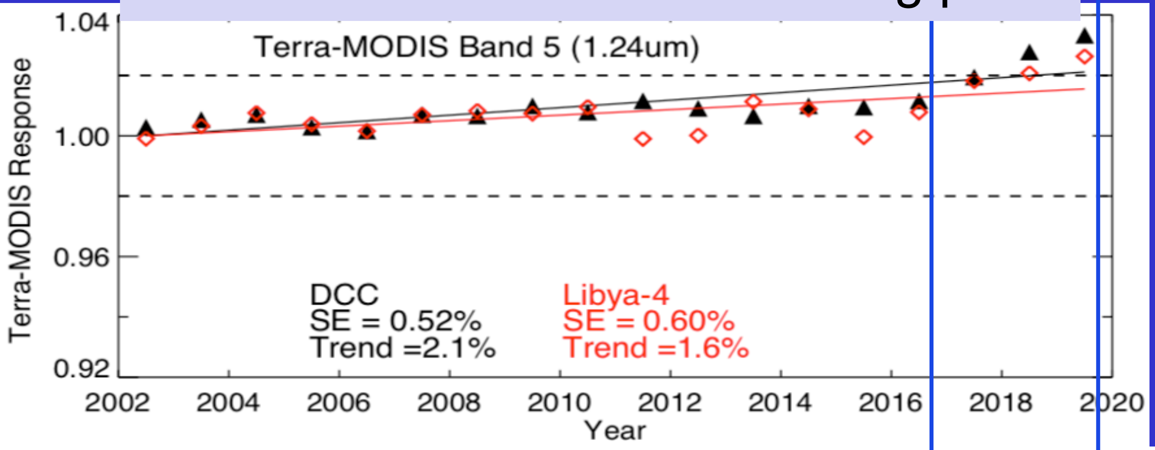
GEO and imager CALIBRATION

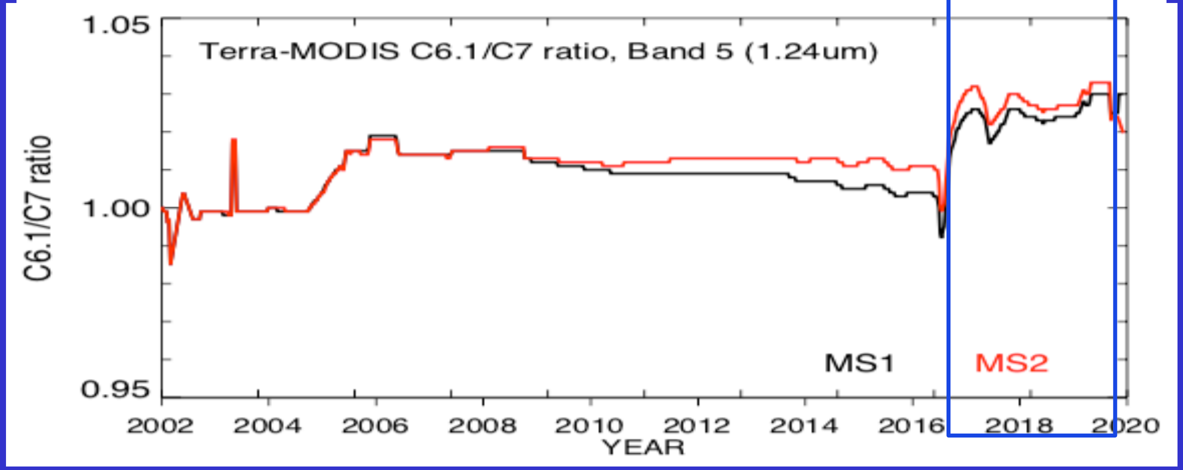
MODIS Collection 7 to C6.1 scaling ratios

- CERES imager and geostationary calibration group (IGCG) is evaluating preliminary version of the next MODIS collection scaling ratios
- Changes in Aqua-MODIS for all reflected solar bands is less than 1% and for Terra-MODIS visible band calibration is 1% or less
- Terra-MODIS SWIR bands have major calibration update



Our annual calibration monitoring plots



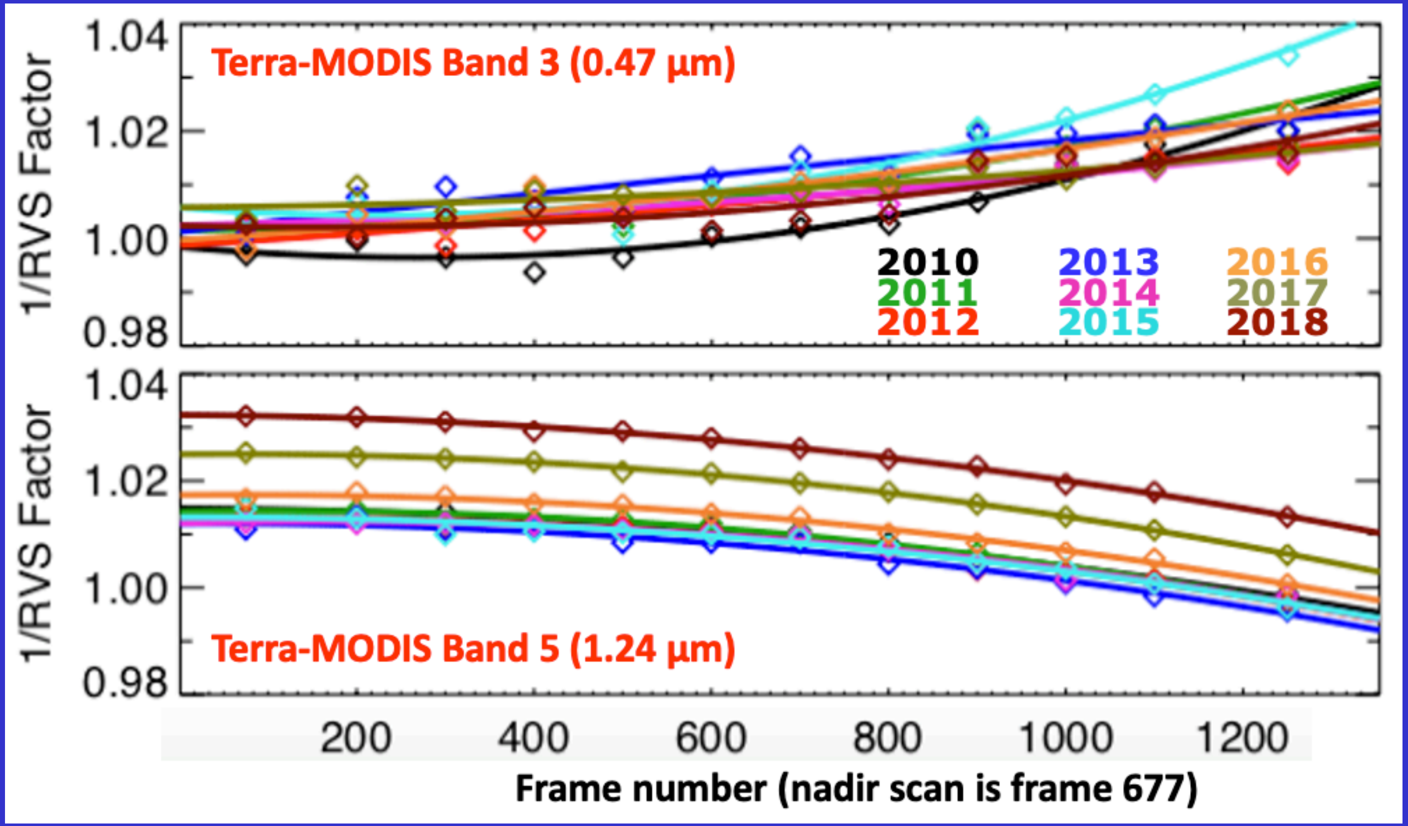


In forward processing mode it is extremely difficult to judge whether to correct the calibration, because you will be applying last year's calibration to the following year

MCST/VCST Collaboration Update

- Independent validation and reporting of RVS drifts in MODIS C6.1 by CERES imager and geostationary calibration group (IGCG) using DCC method*
- Characterization of the polarization sensitivity change over time for the MODIS scan mirror

Terra-MODIS C6.1 RVS drifts, will be removed for C7



*R. Bhatt, D. R. Doelling, A. Angal, X. Xiong, C. Haney, B. R. Scarino, A. Wu, and A. Gopalan, "Response Versus Scan Angle Assessment of MODIS Reflective Solar Bands in Collection 6.1 Calibration," *IEEE Trans. Geosci. Remote Sens.*, vol. 58, no. 4, pp. 2276-2289, April 2020.

Daily monitoring update

- The new GEOs with onboard calibration systems will incrementally update the calibration and there are unexpected gain jumps, these need to be removed

Event	StartDate	EndDate	Notes
B05 10% jump	12/12/2017	12/29/2017	In-correct B05 solar calibration coefficient was used during this period
VNIR Operational Algorithm Update	1/17/2018 Magnitude not cited	2/7/2018	A new calibration algorithm was operationally implemented to reduce the VNIR striping observed since in-orbit. This implementation was accomplished with two steps: the first step was the upload of the new detector non-linearity (Q) LUT for B01/B02/B03 on 01/17/2018 and the second step was to implement the new algorith using Q-scaling on 02/07/2018. This new algorithm resulted in significant reduce in striping at B01/B02/B03 and slight change in the VNIR radiometric calibration accuracy. No change in B05 striping.
VNIR 10% jumps	4/10/2018	4/10/2018	All 6 VNIR channels experienced ~10% jumps in the radioemtric calirbation accuracy due to the incorrect use of solar calibration coefficients
VNIR Operational Algorithm Update	1/17/2018 Magnitude not cited	2/7/2018	A new calibration algorithm was operationally implemented to reduce the VNIR striping observed since in-orbit. This implementation was accomplished with two steps: the first step was the upload of the new detector non-linearity (Q) LUT for B01/B02/B03 on 01/17/2018 and the second step was to implement the new algorith using Q-scaling on 02/07/2018. This new algorithm resulted in significant reduce in striping at B01/B02/B03 and slight change in the VNIR radiometric calibration accuracy. No change in B05 striping.
Unexpected G16 VNIR gain jumps	04/08/2019	04/09/2019	All the G16 VNIR bands experienced a unexpected large jump (>10%) after the GS software update (DO.07.02) on 04/08/2019. An unknown origin of the gains were used after this GS update. On 04/09/2019 the previous solar cal gain values derived with DO.07 using the 03/26 solar cal. data were re-applied to generate L1B data. Visible striping can be observed in the G16 L1B images during this abnormal period.
G16 B02 bias correction	04/23/2019		1)GOES-16 new B02 K-LUT was implemented on GS at 11:00UTC on 04/23/2019(B02 with CWG's delivery. The other bands corrected with CDRL079_FM1_RevF); 2) calibration algorithm with RevG 3) instrument-to-spacecraft alignment angles with CDRL79-FM1_RevM. The major impact is that G16 B02 radiance is reduced by about ~6.2%.

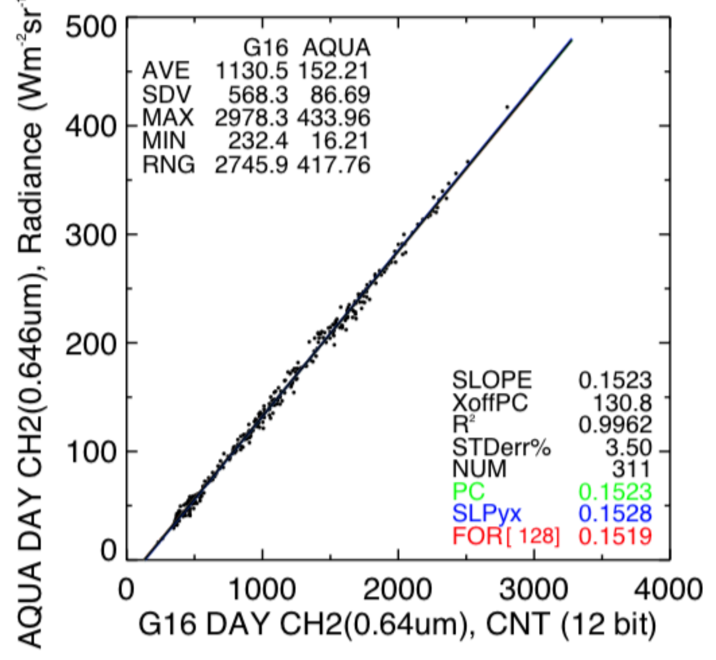
This is a partial list, only listed the visible calibration issues

https://www.star.nesdis.noaa.gov/GOESCal/goes_SatelliteAnomalies.php

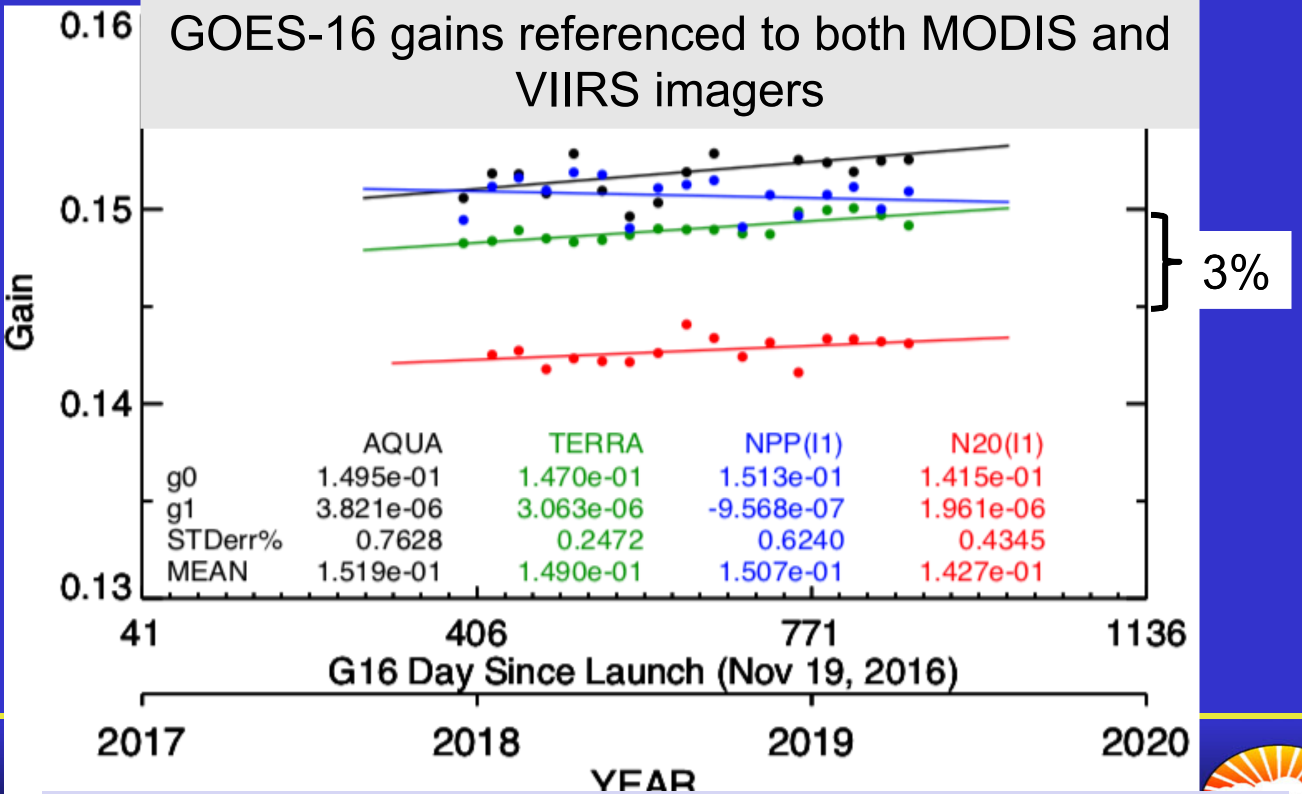
Daily monitoring update

- For Ed4, we inter-calibrate GEO imagers with Aqua-MODIS as the reference by regressing coincident ray-matched radiances monthly.
- We also track the GEO calibration with the other imagers

GOES-16/Aqua-MODIS
Feb 2019



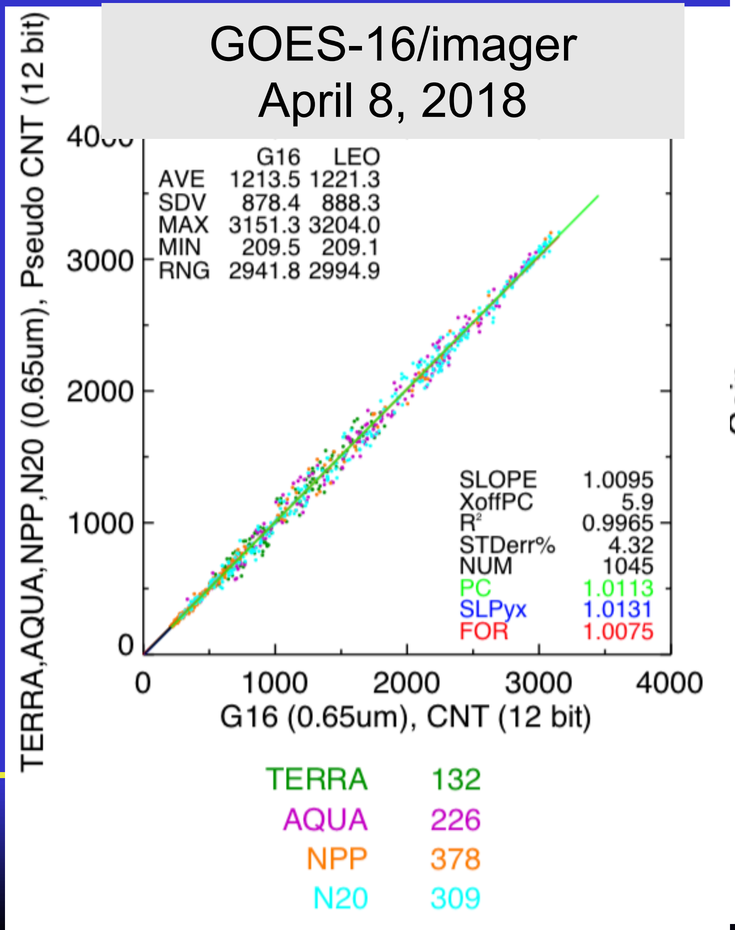
GOES-16 gains referenced to both MODIS and VIIRS imagers

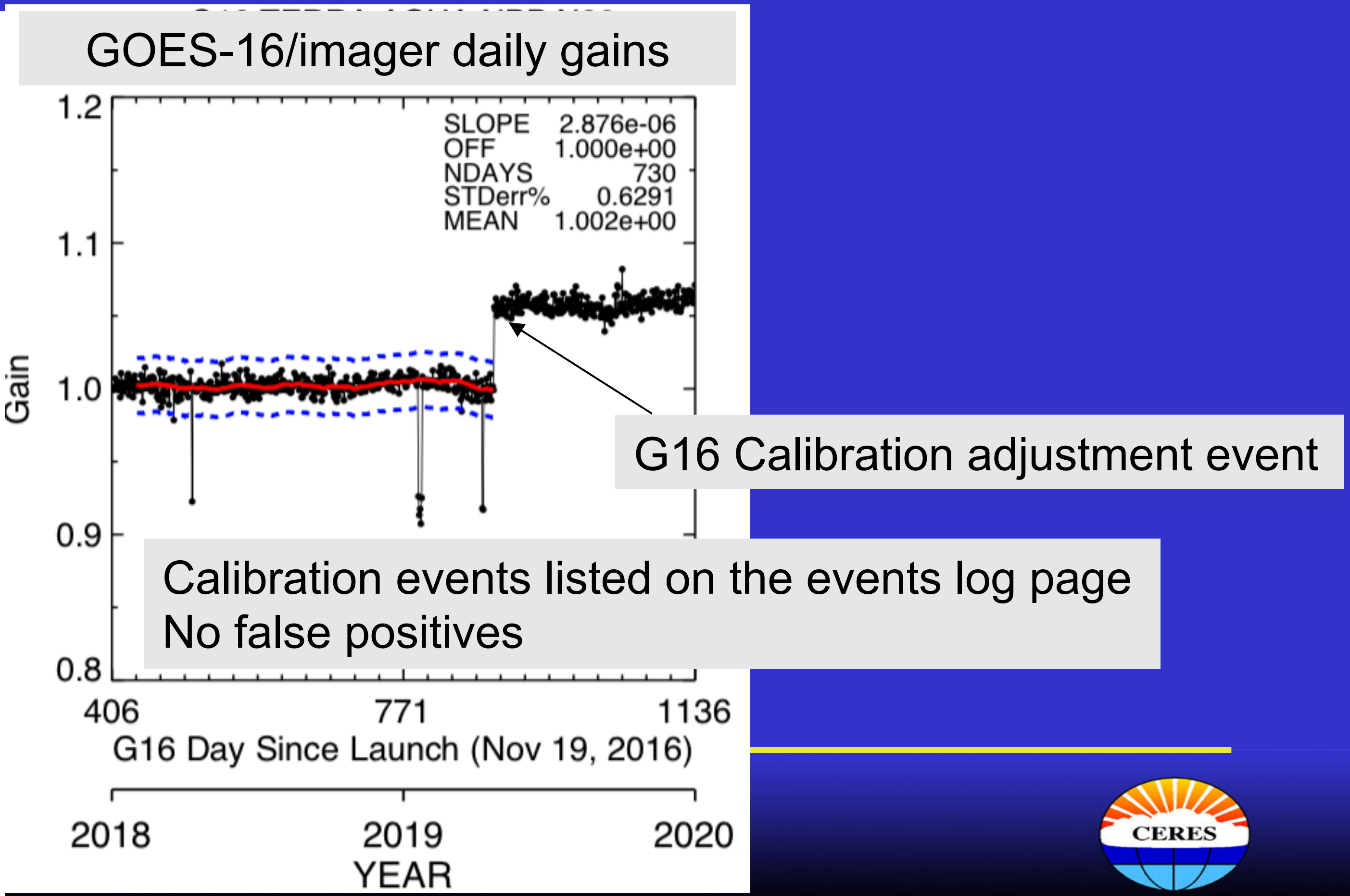


The imager absolute calibration differences are revealed

Daily monitoring update

- By combining both MODIS and VIIRS imagers and using a 0.25 grid provided sufficient sampling for daily monitoring
- Use the mean imager GOES-16 calibration gain to normalize the gains

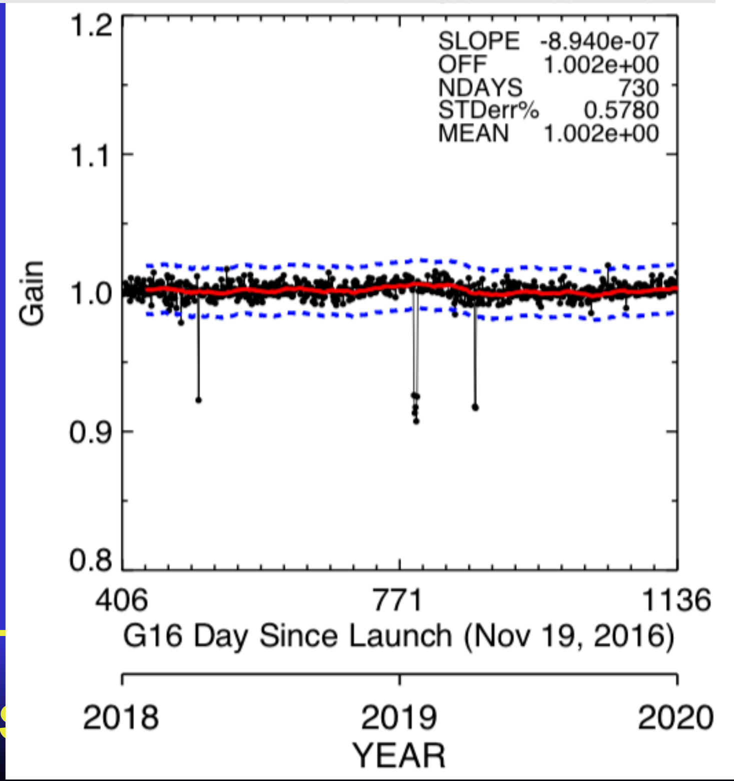




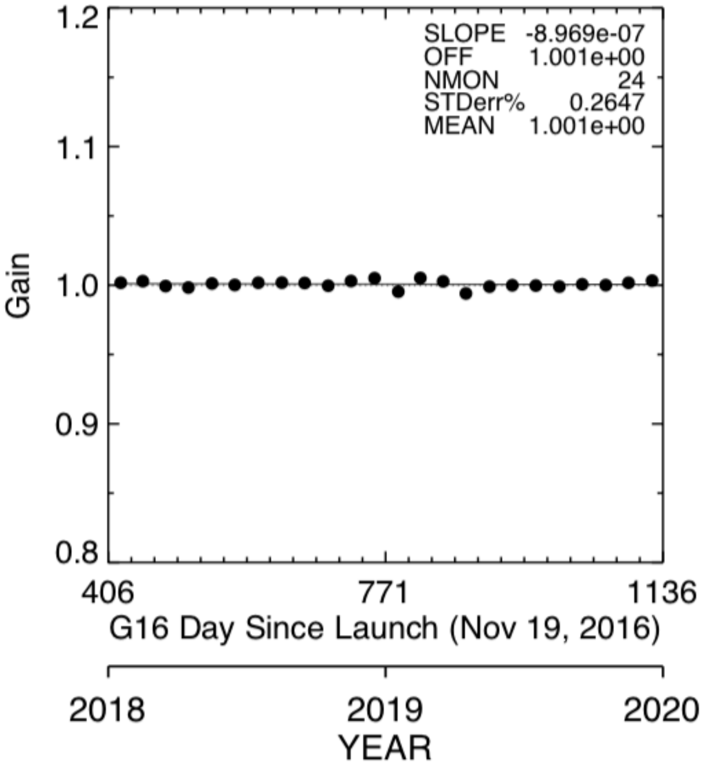
Daily monitoring update

- Any calibration event greater than 3x (1.7%) the standard error (0.58%) can be confidently identified
- Apply the inverse of the daily gain to days with calibration events to use all days in processing
- Next apply to other G16 channels and other GEOs with onboard calibration

GOES-16/imager daily gains after correcting for April 2019 calibration adjustment



Monthly gains computed using the daily data



Conclusion

- FluxByCldType product to be released May 8, 2020
- SSF1deg-N20 Ed1 code delivered
- Looking into transitioning from SYN1deg-Aqua to SYN1deg-N20
  – To be ready when the Terra and Aqua satellites start to drift
- TISA's main effort are the Edition 5 coding improvements
  – GEO SW NB to BB
  – Merge the SSF1deg and SYN1deg codes
  – Implement the SARB, FlashFLUX, and GEO SW and LW NB to BB at the GEO pixel level and then perform gridding
- Calibration activities
  – Continue to work with Jack Xiong's group in evaluating MODIS C7 and VIIRS editions
  – Work with Cloud group to evaluate the MODIS to VIIRS scaling factors
  – Implement GEO daily monitoring algorithm for new GEOs with onboard calibration